ITER Forum Website Update June 2010

B.J.Green

1. Europe's bold move on climate
2. We don't need renewable energy fund
3. JET Capabilities in support of ITER
4. JET gets new wall to prep for ITER
5. First ITER Components Transported
6. Simulating the Sun
7. Clean energy research still needed
8. Pacific islands 'growing, not sinking', say researchers
9. James Hansen keen on next-generation nuclear power

1. Europe's bold move on climate

Ben Webster, The Times, May 27, 2010 12:00AM

http://www.theaustralian.com.au/news/world/europes-bold-move-on-climate/story-e6frg6so-1225871740545

EUROPE was tipped to introduce a new plan overnight to combat global warming, committing it to the world's most ambitious targets.

The surprise plan proposes a massive increase in the target for cutting greenhouse gas emissions in this decade. The European Commission is determined to press ahead with the cuts despite the financial turmoil gripping the bloc, even though it would require EU member states to impose far tougher financial penalties on their industries than are being considered by other large economies. The plan, to cut emissions by 30 per cent on 1990 levels by 2020, would cost the EU an extra $58 billion a year by 2020, according to a draft of the commission's communication leaked to The Times. The existing target of a 20 per cent cut is already due to cost $84bn.

The commission will argue that the lower target has become much easier to meet because of the recession, which resulted in the EU's emissions falling more than 10 per cent last year as thousands of factories closed or cut production. Emissions last year were already 14 per cent below 1990 levels.

Business leaders fear thousands of jobs could be lost and energy bills could soar. Carbon taxes on road fuel, heating and other sources of emissions could be introduced, with proceeds reinvested in renewable energy. The EU's present policy is to wait for other countries to commit to equivalent action before raising its target to 30 per cent "as part of a genuine global effort". But after the failure of the Copenhagen climate summit, a global deal on cutting emissions is unlikely to be agreed until the end of next year.

Climate Commissioner Connie Hedegaard will make the case for the EU to commit itself unilaterally to a 30 per cent cut to inspire other countries to follow suit and accelerate the development of low-carbon industries. The draft communication says: "The extra economic effort needed to reach 30 per cent - while still substantial - has fallen. Both the international context and the economic analysis suggest that the EU is right to continue preparing for a move to a 30 per cent target. With the 20 per cent target reachable with less effort, and the carbon price low, it also acts as a much less powerful incentive for change and innovation."

The plan also says that the higher target would reduce air pollution from fossil fuels and improve the health of millions of people, generating up to $14bn a year in economic benefits from having a healthier population. The draft commission document raises the possibility of trade wars by suggesting EU industries could be protected by imposing border tariffs on imported goods from non-EU countries with less stringent emission controls.

Jeremy Nicholson, director of the Energy Intensive Users Group, said: "A unilateral move to 30 per cent would damage the European economy at a time when we can ill afford it."

The Times

2. We don't need renewable energy fund

Gary Johns, The Australian, May 27, 2010 12:00AM 17 comments

http://www.theaustralian.com.au/news/opinion/we-dont-need-renewable-energy-fund/story-e6frg6zo-1225871762164

THE Swan budget will soon have a big hole. Its projected "early" return to surplus will not happen because there is no way the resource super-profits tax can survive in the form proposed.

Rue the day then that having spent massively on subsidising renewable energy in earlier budgets, the government had another dip into the taxpayers' pocket in the present budget. The $652 million Renewable Energy Future Fund announced in the budget was apparently plucked from nowhere just days before the speech. The Treasurer announced that the fund would "leverage private sector investment to support renewable energy projects, and the development and deployment of low-emissions technologies".

The trouble is there is some convincing evidence to suggest that present low-emission technologies are not going to do the job. It seems that the world needs an "energy technology revolution" and that is going to require a great deal of government investment in energy research and development. Labor has pledged money to hard science in coal sequestration, which is laudable, if one accepts the need at all, but renewables are another matter altogether.
The Swan renewable fund is unlikely to fit the bill.

Apart from the massive amounts wasted in the rollout of roof insulation and solar panels, the whole concept may be a waste of money because it is about subsidising old technologies.
My generation, the late baby boomer generation, had hopes that windmills and solar panels would power the world. When Amory Lovins produced his seminal Soft Energy Paths in 1976, we swooned at the thought that renewables would save the world from running out of resources. Well, 35 years on, the soft path is still a chimera.

We now know that no Australian prime minister will risk his job to get the numbers at a double dissolution election to force an emissions trading scheme on the economy. It is just as well. The Hartwell group (the London School of Economics and Oxford University) argues that mass improvements are needed across many technologies, requiring the determined participation of governments. They suggest partially funding the required research and development with a "slowly rising but initially low carbon tax" that would avoid undermining economic growth. This is a major challenge to both Labor and the Coalition, not to mention the Henry tax agenda.

Similarly, a paper from Bjorn Lomborg's group, the Copenhagen Consensus Centre, by Galiana and Green, has strong reservations about the necessity for a strong price signal, of the kind Kevin Rudd's Carbon Pollution Reduction Scheme aimed to achieve, to bring about "major technological breakthroughs". They argue that there is little or no evidence that carbon pricing

would induce big technological breakthroughs. They ask why countries such as Australia, a big emitter and heavily dependent on coal, would accept rapidly rising carbon prices without some assurance that these would soon be alleviated by technological breakthroughs.

Galiana and Green describe the present path as a policy of "brute force" mitigation to meet arbitrary and time-specific emission reduction targets. The fact is that CO2 emissions cannot be capped unless there are good, non carbon-emitting energy and-or energy technology substitutes. They argue that a policy that sets aside targets and puts the up-front emphasis on energy research and development, infrastructure, and deployment of new technologies is workable. This means that the real game is a technology race and simply subsidising the spread of present technologies will not cut it.
In this respect, buying green jobs, which is the preference of the ACTU and the ACF, is likely to delay the day of the technology breakthrough.

The ACTU-ACF paper released last week, "Creating Jobs, Cutting Pollution", is really about sustaining the romance of Lovins. But simply hoping to abate CO2 emissions with old and very expensive "renewable" technology will make Australia poorer and no more likely to adopt the new technologies when they arise.

Galiana and Green argue that sooner or later the proponents of the present target-led and carbon pricing-based climate policy options will have to concede that putting the "cart" (large cuts in emissions) before the "horse" (the technological means for making the cuts) is a doomed approach. The message for Australia is to invest in research and development in the technologies it knows best, that is, coal, and forget wasting money on technologies that do not cut the "major technological breakthrough" test.

Big picture politics as opposed to retail politics will return with a rush in early 2011, and no matter who is prime minister that person will need to be far better prepared on this issue than is the case for Labor and the Coalition at the moment. I may be a climate change sceptic, but the realist in me suggests that the push for a "solution" to climate change will not abate.

Adaptation is still the best policy, but the search for a technological fix at no damage to the economy is the one that governments must support. Gary Johns was a minister in the Keating Labor government.

3. JET Capabilities in support of ITER

http://www.jet.efda.org/jet-iter/jets-capabilities-in-support-of-iter/

The capabilities of JET can advance experience and understanding in many areas essential to ITER:

- JET extends experience of in-vessel remote handling techniques, based on its comprehensive Remote Handling facility.
- due to the size of JET, it is the best suited facility to study the confinement of the fusion products, the fast alpha particles. The fast alpha particles have to be sufficiently confined in order to transfer their kinetic energy to other plasma particles (and thus maintain extreme plasma temperatures), but if they’re too confined, they hamper the fusion process by dissolving the D-T fuel and increasing plasma radiation losses. At JET, we can produce fast alphas either in D-T fusion, or by their acceleration in plasmas on special radiofrequency waves.
- due to its unique tritium handling capability, JET can actually study plasmas with a high rate of Deuterium-Tritium (D-T) fusion reactions (commonly known as “burning plasmas”)
- JET provides key contributions to the material studies and plasma-wall interaction

studies due to JET's unique beryllium handling capability (beryllium being the design choice for the ITER first wall, i.e. the plasma facing material)

The Mascot servo-manipulator master station with operators in the Remote Handling control room (left) and the slave unit inside the JET torus. Ongoing experimental studies on JET provide detailed groundwork for ITER operations. These include further optimisation of the "basic" operating scenario and development of "advanced" scenarios with a potential for increased fusion performance and steady state operation. An important part of this work is devoted to the development of extensive real-time control and powerful heating systems and to the development of new plasma diagnostics and heating schemes. JET plays a dominant role in the international tokamak database that is used for extrapolations to ITER (see scaling laws), with data closest to the ITER working point. In addition, the JET experimental programme allows continuous benchmarking in order to develop an integrated set of modelling tools the preparation and analysis of ITER experiments.

As part of the "JET programme in support of ITER" proposed for 2005-2010, three major projects for upgrading JET were approved and launched. They are the "ITER-Like Wall", the "Neutral Beam Enhancement" and the "High Frequency Pellet Injector".

4. JET gets new wall to prep for ITER

An elaborate, remote-controlled revamping of JET has begun.
Toni Feder, Physics Today, December 2009, page 24

http://ptonline.aip.org/journals/doc/PHTOAD-ft/vol_62/iss_12/24_1.shtml?bypassSSO=1

The nearly 5000 carbon tiles that line the inside of the Joint European Torus, the world's largest tokamak, are being unbolted. They're to be replaced with beryllium and tungsten tiles, the same combination planned for ITER, the international prototype fusion reactor under construction in Cadarache, France. The €100 million (roughly $150 million) JET makeover began on 26 October and is scheduled to be done by the end of next year, with ITER-relevant experiments—including the fusion of tritium and deuterium—to start soon thereafter.

Located at the UK's Culham Centre for Fusion Energy, the 26-year-old JET holds the fusion power record, 16 MW for 1–2 seconds, produced in 1997. More than once it came close to being shuttered. "It is a project that had to fight for going ahead every time," says director Francesco Romanelli. The machine's interior has been modified several times, he notes. "It was built in a very flexible way, so it's been able to adapt every time to new requests from researchers." Over the past decade, adds UK fusion program director Steven Cowley, "JET has been busily doing science. There is nothing at the scale just below ITER except JET. It's the only machine on which you can practice for ITER, so the lead up to ITER is a critical time for JET. Everything now is preparation for ITER."

"A bit of cookery"

The mission of ITER, which will start up no sooner than 2018, is to create power by fusing tritium and deuterium. Carbon, a typical tokamak lining material, "sucks up tritium like crazy," which makes the walls radioactive, says Cowley. So, although ITER is due to start out with carbon walls, a switch to tungsten and beryllium is planned before the machine goes full throttle. Tungsten has been used successfully in the ASDEX Upgrade, a tokamak in Garching, Germany. "Nobody believed it would work," says the facility's director, Hartmut Zohm. "If tungsten gets into the plasma, it radiates a lot at these temperatures" of up to 200 million degrees. Anything that radiates UV and x-ray photons cools the plasma by taking heat from electrons. But tungsten has the highest melting point of any metal and minimal erosion under plasma particle bombardment, so, Zohm says, "if you can prevent it from getting into the plasma, it's a great wall material." The plan at JET—and ITER—is to use tungsten in the diverter, where particles strike the wall

and, along with impurities, are swept out of the tokamak. The remaining roughly 90% of the wall will be lined with solid beryllium and beryllium-coated tiles. Like carbon, beryllium has the advantage of low atomic number and doesn't cool the plasma. "What we've learned is that a bit of cookery goes into fusion plasmas. The impurities that get into the plasma are critically important," says Cowley. Because beryllium radiates much less than tungsten, it is less damaging. Beryllium, he adds, "is a nasty substance. It's bad for your lungs. But JET is equipped to work with it."

Remote manipulations

To avoid exposure to the radioactive walls, meet exact specifications, and provide practice for ITER, the makeover is being done remotely by human-controlled robots. "This is a huge project," says Gary Hermon, a shift leader for the robotic work. "We have been practicing with simulations and a physical mockup for two years." Hermon is one of about 50 people involved in the relining of JET, which is being carried out night and day over about 14 months. "I generate scripts. Tighten this bolt, go back and torque that bolt. Due to the complexity and diversity of the tasks, they are broken down into very simple steps," Hermon says.

Besides the tiles being replaced, the diagnostics systems are being upgraded. "Passive and active systems will be installed in, on, and behind the tiles," says Cowley. "These will measure almost every physical quantity of interest—plasma temperature, density, fields, heat loads, et cetera."

The JET robotics system is a master–slave pair. "The operator sits between two dangling articulated [master] arms. At the ends are grippers," says Hermon. The arms, each about a meter long, have eight degrees of freedom. "You can pitch the hand, lift the wrist up and down, roll in a way a human hand can't . . . ," says Hermon. The master arms are in front of a bank of computers that give a three-dimensional view of the inside of the tokamak, some 200 meters away. Synchronized to the master arms are the slave arms, which do the actual work from the end of a several-meter-long boom. "We have feedback on the system," says Hermon. "You can feel weight, or rubbing. We don't use robots as manipulators. There is always a man in the loop. We have submillimeter tolerance. You need a human."

As part of their interviews for the robotic handling team, operators had to use robotic arms to stack toy building blocks. "You have to be dexterous," says Hermon. "A good operator can build a tower. He can go in and feel if a block is moving." The JET work can be delicate, he adds, "almost like threading a needle. And plug-in sockets, for example, are easily damaged because they have ceramic insulation. We are not allowed to damage the surface at all." The individual beryllium tiles weigh up to about 12 kg and cost tens of thousands of dollars, he adds.

"There is an enormous amount of work, and so many strands that have to come together," says Hermon. "Some components are still being manufactured, and there is the occasional last-minute design change. The major challenge is sheer time."

Scaling up to ITER

JET "will be a completely new machine when it comes back," says Cowley. Although tungsten and beryllium have each been tested alone, says Romanelli, "the combination has never been tested. Our plan is to demonstrate that we can run up to the highest performance reliably with the combination." Experiments exploring how the new wall behaves and any required modifications will take about three years, he says. Then, for the first time since 1997, JET will embark on a tritium campaign in late 2013.

ITER will be about twice JET's size, its pulses will be about 20 times as long (400 seconds compared with about 20 seconds at JET), and it is intended to produce around 30 times the power (500 MW compared with 16 MW). Still, says Mario Merola, who oversees planning for ITER's plasma-facing components, "we need the information coming from [JET] for finalizing the scenarios for the ITER machine, which will have exactly the same situation as far as the plasma-facing wall.

“JET will address major scientific topics,” Merola says. “For example, how the melted layer of beryllium—which results from large, fast energy deposition in off-normal plasma events, like vertical displacement or plasma disruptions—behaves under electromagnetic loads, and how eroded beryllium penetrates into the gaps between tungsten tiles. We will also get information on the behavior of tungsten under high and cyclic thermal loads and on how the plasma behaves with a tungsten diverter.” Cooling the much larger number of tiles in ITER using pressurized water will be a technological challenge, he adds. JET is also key for training physicists and engineers in remote handling, beryllium and tritium handling, and burning plasmas, among other things. Merola says he doesn’t expect the JET results to lead to changes in the ITER design, “but they will provide us with information on the lifetime of components, and from a physics standpoint, how the plasma behaves with a combination of beryllium and tungsten. We are very keen on getting these results.”

5. First ITER Components Transported

http://www.iter.org/

The first conductors produced for ITER's toroidal field coils were transported by truck and then boat in March 2010 between the manufacturer, Nippon Steel in Kyushu, Japan and Toshiba in Yokohama where trial winding will be performed.

6. Simulating the Sun

Spiraling Costs Threaten International Fusion Reactor Project
By Christoph Seidler and Christian Schwägerl

http://www.spiegel.de/international/world/0,1518,696922,00.html

The planned ITER fusion reactor in France is supposed to replicate conditions inside the Sun to produce limitless clean energy. But skyrocketing costs are putting the international project at risk. Now Germany's research minister has said Berlin will not write a blank check for the technology.

From the air, the construction site looks like a sandbox for giants. The meticulously leveled area, which is located in the middle of lush pine forests near the southern French town of Saint-Paul-les-Durance, is waiting for the ground-breaking ceremony in July. Here, on yellowish-red Provencal soil, the international nuclear fusion reactor ITER is supposed to be built in what will be one of the largest research projects in the world.

In recent months, construction workers are said to have moved soil with the total volume of the Great Pyramid at Giza. And that is just the beginning. The first buildings will soon be erected here, forming the site's own small town. The largest building will house the reactor, where as of 2026 the hydrogen isotopes deuterium and tritium will be fused in a controlled reaction to form helium, delivering energy on the scale of a power plant. It's the same process that operates within the sun, and temperatures in the interior of the reactor could reach 100 million degrees Celsius (180 million degrees Fahrenheit).

Proponents of the project argue that what is at stake is nothing less than the energy of the future -- a process of energy production that uses a fuel that is available in almost infinite quantities, and that produces nearly no waste. For the first time, a fusion reactor would produce more energy than is necessary for its operation.
Opponents, however, see the multi-billion euro project as a modern white elephant. Now it has been revealed that ITER's construction costs are exploding. In a worst case scenario, the whole

project could be at risk.

Need for Fresh Cash
Originally, the futuristic reactor was supposed to cost around €5 billion ($6.15 billion). That was the figure given in 2006 when the participating partners -- the European Union member states, China, India, Japan, Russia, South Korea and the United States -- agreed to fund the project. The Europeans were supposed to shoulder 40 percent of the costs, with the remaining partners taking on 9 percent each. But a recent estimate by the European Commission has revealed that the total costs have already tripled to €15 billion, as a result of higher raw material prices and new safety requirements, among other expenses.

The Europeans alone would have to provide €7.2 billion, and further increases in costs cannot be ruled out. But where is the money supposed to come from? Officials in Brussels have drawn up two scenarios: Either member states must inject fresh cash directly, or the EU's research budget will have to be increased by the required amount. Ideally, the eurocrats would like to have a kind of blank check, whereby member states would already guarantee to cover additional future costs. Each of the scenarios would mean a sharp increase in Germany's contribution, which could reach as much as €1 billion, instead of the originally agreed €540 million. Now Germany's research minister, Annette Schavan, has spoken out against the burgeoning costs. "It's normal for research projects to have increases in costs, but a rise of 300 percent is unusual and not acceptable," Schavan said Wednesday at a meeting of EU research ministers in Brussels.

"ITER is a very important project for Europe," Schavan stressed, adding that the project could not be put at risk for that reason. She called for greater transparency: "We need different management, and we need a clear outlook." Schavan also rejected the idea of a "blank check" for the project. "We can't pass a resolution which simply says we want (the project) and we will see later how it can be financed," she said Wednesday. In light of the "unusually difficult situation in all national budgets," member states must be able to stem the costs, she added.

Downsizing the Project
According to sources in the Research Ministry, the German government wants to keep as many options for energy production open as possible -- and it still favors fusion research. But Schavan warned ahead of Wednesday's meeting that the government would not support fusion research "at any price." Berlin now wants a new approach to financing the reactor, which would be drawn up by the European Commission. Schavan has indicated that the reactor design might have to be revised. That could mean, for example, that the project will end up being significantly smaller than currently planned.

Such a change "is not currently foreseen," ITER's deputy director Norbert Holtkamp told SPIEGEL ONLINE. "In principle, however, it is absolutely possible -- but only if all the partners agree to it." Getting that agreement could be complicated, as could negotiations over more money for the project. The project's supervisory body, known as the ITER Council, will next meet in mid-June near Shanghai. By then, the Europeans need to be clear about how they want the project to proceed.

Nuclear scientists insist on the importance of the project. "Fusion is an option that we must pursue urgently," argued Günther Hasinger, head of the Max Planck Institute for Plasma Physics, in an interview with SPIEGEL ONLINE. "We still have no silver bullet which we can use to meet the electricity needs of the world at the end of the 21st century, which will be about six times larger than today."

Putting the Puzzle Together
France and Germany have both made suggestions aimed at sinking the costs by some €600 million, EU diplomats in Brussels say. But that likely isn't enough. The problem is that the way the project is designed virtually assures inefficiencies. Seven partners are working together on ITER; all of them have access to the blueprints and the requisite documents. The only exceptions are

drawings relating to the equipment responsible for producing the tritium fuel in the reactor.

In contrast to other, similarly ambitious international projects, like the Large Hadron Collider particle accelerator in Geneva, the partners are not simply funneling money into a collective fund. Instead, each country is manufacturing part of the necessary components. The parts will then be put together in France in the hopes that, when the puzzle is complete, it will work. It seems inevitable that, given such structures, some of the work will be needlessly replicated.

Additional extra costs must also be taken into account. For example, the Japanese are receiving a small fusion research reactor and a supercomputer as compensation for the fact that ITER is not being built in their county but in faraway Europe.

The Price of Collaboration
"This is the price you have to pay if you want to develop technology in an international collaboration," said Holtkamp. "It is certainly possible to build a system more efficiently if you want." At the end of the day, he said, it would have been cheaper if one country had developed the reactor by itself. "But then it would have had to pay for everything." Keeping costs down was not, however, the main priority when the ITER project was set up, Holtkamp said: "This is about creating a knowledge base from which all partners will benefit equally."

The participating countries did, however, take the built-in problem of inefficiency into account -- in order to be able to develop as much of the valuable fusion technology at home as possible. This could become a problem, now that financial concerns are calling the whole project into question. One thing is clear, however, Holtkamp argued: "Delaying a project never saves money. It always becomes more and more expensive."

7. Clean energy research still needed

http://www.abc.net.au/rn/breakfast/stories/2010/2891866.htm

With an emissions trading scheme on hold and the local renewable energy sector struggling for traction, Australia is still a long way from creating a sustainable energy mix. The key issue is that existing alternative technologies are in their infancy - and all face problems and need big improvements.

And it's the same story with nuclear power, according to one of America's top energy scientists. Professor Eric Isaacs is in Australia this week to deliver the keynote address at the Cleantech Science and Solutions conference in Melbourne.

8. Pacific islands 'growing, not sinking', say researchers

Rowan Callick, Asia-Pacific editor, The Australian June 04, 2010 12:00AM

http://www.theaustralian.com.au/news/pacific-islands-growing-not-sinking-say-researchers/story-e6frg6xf-1225875237545

RESEARCH on 27 Pacific islands to be published in a leading scientific journal has found that during the past 60 years, all but four have either kept their size or have grown, some by 20-30 per cent.

The findings, by Paul Kench at Auckland University and Arthur Webb at the South Pacific Applied Geoscience Commission in Fiji, appear to tell a different story from claims that many islanders are in danger of losing their homes as a result of climate change-driven surges in sea levels. "There are two separate issues here," Dr Webb said yesterday from Suva. "The first, which we have examined, is shore line erosion. The second is susceptibility of very low-lying islands to

inundation -- to which we do not bring anything."

Dr Kench told ABC the good news from their research is that "we've now got evidence that the physical foundations of these islands will still be there in 100 years". Their results show that 43 per cent of islands remained stable and a further 43 per cent had increased in area over the time frame of the analysis.

Australia's National Tidal Centre, based at the Bureau of Meteorology in Adelaide, runs the South Pacific Sea Level and Climate Monitoring Project, the only Pacific-wide operation monitoring sea-level changes as they occur.

It has found that such changes vary enormously around the region but that generally seas are rising. At the present pace, 12.7 per cent of a typical Kiribati island, for instance, will have been eroded by the start of the 22nd century, according to the Tidal Centre's observations. The research by Dr Kench and Dr Webb, which is being published in the journal Global and Planetary Change, used historical aerial photos and satellite imagery to study changes in the land surface of 27 islands.

They reveal that local sea levels have been rising by an average of 2 millimetres per annum, yet only four islands have diminished in size since the 1950s. The others have retained their size or grown. The researchers do not deny that climate change is having an impact, but they have discovered that Pacific islands are considerably more adaptable to such change than previously conceived. Dr Kench told the British magazine New Scientist: "It has been thought that as the sea level goes up, islands will sit there and drown. But they won't. The sea levels will go up and the island will start responding."

While Tuvalu is often predicted to be the first Pacific nation to be inundated, Dr Kench and Dr Webb have discovered seven islands there have increased by an average 3 per cent since the 1950s, one gaining nearly 30 per cent.

9. James Hansen keen on next-generation nuclear power

Leigh Dayton, Science writer, The Australian March 10, 2010 12:00AM

http://www.theaustralian.com.au/higher-education/james-hansen-keen-on-next-generation-nuclear-power/story-e6frgcjx-1225838858482

RENEWABLE energy won't save the planet so it's time to go nuclear, according to one of world's most high-profile climate scientists.

"We should undertake urgent focused research and development programs in next generation nuclear power," said atmospheric physicist James Hansen, head of NASA's Goddard Institute for Space Studies and adjunct professor at Columbia University's Earth Institute in New York. While renewable energies such as solar and wind were gaining in economic competition with coal-fired plants, Professor Hansen said they wouldn't be able to provide baseload power for years to come.

Even in Germany, which pushed renewables heavily, they generated only 7 per cent of the nation's power. "It's just too expensive," said Professor Hansen, an expert in climate modelling, planetary atmospheres and the Earth's climate. "Right now, fossil fuels are the cheapest form of energy, except for operating nuclear plants," he said on the first day of a lecture tour in Australia. According to Professor Hansen, because the threat of global warming was so serious, nations such as the US, China and even Australia must crank up support for so-called third and fourth generation nuclear systems.

"Current nuclear plants are the second generation. The third generation is ready to build now," he

explained, pointing to conventional light water reactors, which generated heat by the fission of uranium fuel. Two fourth-generation technologies are on the drawing board. Fast reactors use liquid sodium metal as a coolant for the fission of metallic solid fuel, including existing nuclear waste and weapons-grade uranium and plutonium.

Thorium reactors use fluoride salt as the medium for the energy-producing nuclear reaction, so they don't require production of fuel rods. Professor Hansen admitted he was a late convert to advanced nuclear power. "But fourth generation solves two of the problems that made me sceptical," he said.

"One is nuclear waste. It uses over 99 per cent of the fuels, while second and third generations use less than 1 per cent, leaving a waste pile with a half-life of 100,000 years. Fourth generation burns almost all the fuel and waste has a half life of decades." No commercial scale fourth-generation plants exist, but seven nations, including Japan, France and China, have expertise or research and development projects. Which will get their first? "That's an open question," according to Professor Hansen.